“Modeling the MER Mission”

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Outline

- Mars Exploration Rover Mission
- Mission Operations Modeling
- MER Brahms Model
- Brahms Model Affecting Design of Mission Operations
- Predictive Model of Mission Operations
- Lessons Learned

Mar Exploration Rover Mission “Find Past Existence of Water”

- Mars Exploration Rovers (MER)
  - Spirit (MER-A) at Gusev Crater
    - Reached Mars on Jan 4, ’04
  - Opportunity (MER-B) at Meridiani Planum
    - Reached Mars on Jan 25, ’04
  - 90 day mission which was extended.

- Science Payloads
  - Panoramic Camera:
    - Providing the geologic context
  - Rock Abrasion Tool
  - Mössbauer Spectrometer
    - Identifying Iron-Bearing Minerals
  - Miniature Thermal Emission Spectrometer
    - Identifying Minerals at the Site

What is Mission Operations?

“The control of one or more information gathering devices on board a vehicle in space and the associated operation of the vehicle systems in order to support information gathering.”

Why Work Practice Modeling for Mission Operations?

- New designs for
  - Facilities
  - Organization
  - Processes
- Complex work system
  - Scientists and Engineers
  - 24/7
  - Multiple Time Zones
  - Data Systems (new & legacy)
- Design close to implementation stage
- Trial and error of design during Operations Readiness Tests

Where did data for model come from?

- JPL’s Tactical Timeline in Excel spreadsheets, design specifications, software documentation, etc.
- Participated in Mission Design Team’s design sessions
- Interviewed people that were part of MER mission operations.
- Observed JPL’s Operational Readiness Tests.
**What to model?**

- Organizational Structures and Roles
- Operational procedures for roles
- Engineering and Science decision making and planning
- Rover on Mars
  - Receive commands from Earth (Uplink)
  - Command execution
  - Science Payload/Instrument
  - Capture of Science data
  - Send data back to Earth (Downlink)
- Flow of Mission data
  - From Downlink to Uplink to Downlink of science and engineering data
  - Creation, flow and use of intermediate data
  - Communication between people, and between people and systems
- Uplink rover command generation

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**MER Organization**

**Mission Operations at JPL**

- 50 Science Team Members
- 30 Engineering Team Members
- Two Rover Teams (MER A & B)
- 25 STM & 15 ETM per Rover Team
- Two Shifts per Martian Day/Sol
- Shift handovers
- 4 floors within building
- 90-Sol Minimal Mission Duration
  - Jan 2004 - Mar 2004
  - MER A & B Operations overlap
  - Different Time Zones (2 on Mars)

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**MER Organization Model**

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**Uplink Tools Process Flow**

(Similar to traditional “Order Processing”)

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**MER Information Model**

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**Clock, Schedule and Agents**

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Issues of Modeling a Mission Operations

- Actual Work Practice was different from design
  - We know this from our theory of work practice
  - How useful is model in design?
- Unable to predict workflow failure
  - Round-Trip data tracking issue not identified
    - This could have been identified and solved in model design but …

Much detail about mission data and systems needed

How Useful is Model in Design?

- Synchronizing Communications of Key Personnel
  - People could not verbally communicate information because they needed to be in different places at the same time for meetings
- People’s work hours were too long
  - A shift was about 8 to 10 martian hours

Other Uses of MER Brahms Model

- Procedures for Mission Operations Personnel
  - Creation of huge paper poster
- Analysis of Mission Operations
  - Mars-based time versus Earth time (24 x 7 & 8 hours)
- Simulation Visualization
  - Timeline view of information on Rover Activity Plan
  - Communication networks creation and growth

Predicting Workflow Failure: SAP and MAPGEN Scenario
### What have we learned?

- How to model Mission Operations Systems
- Level of detail to model
  - More narrow/deep or more broad/shallow
- Use of BRAHMS?

#### Representation
- Mars time vs. Earth time
- Multiple MER teams
- Systems
- Information flow
- Plans and schedules

#### Usefulness for mission designers
- Not easy to retrieve information
- Not easy to change model
- Difficult to model things
- Difficult to determine needed level
- Difficult what-if scenarios